2017

MASSACHUSETTS CLEAN ENERGY INDUSTRY REPORT

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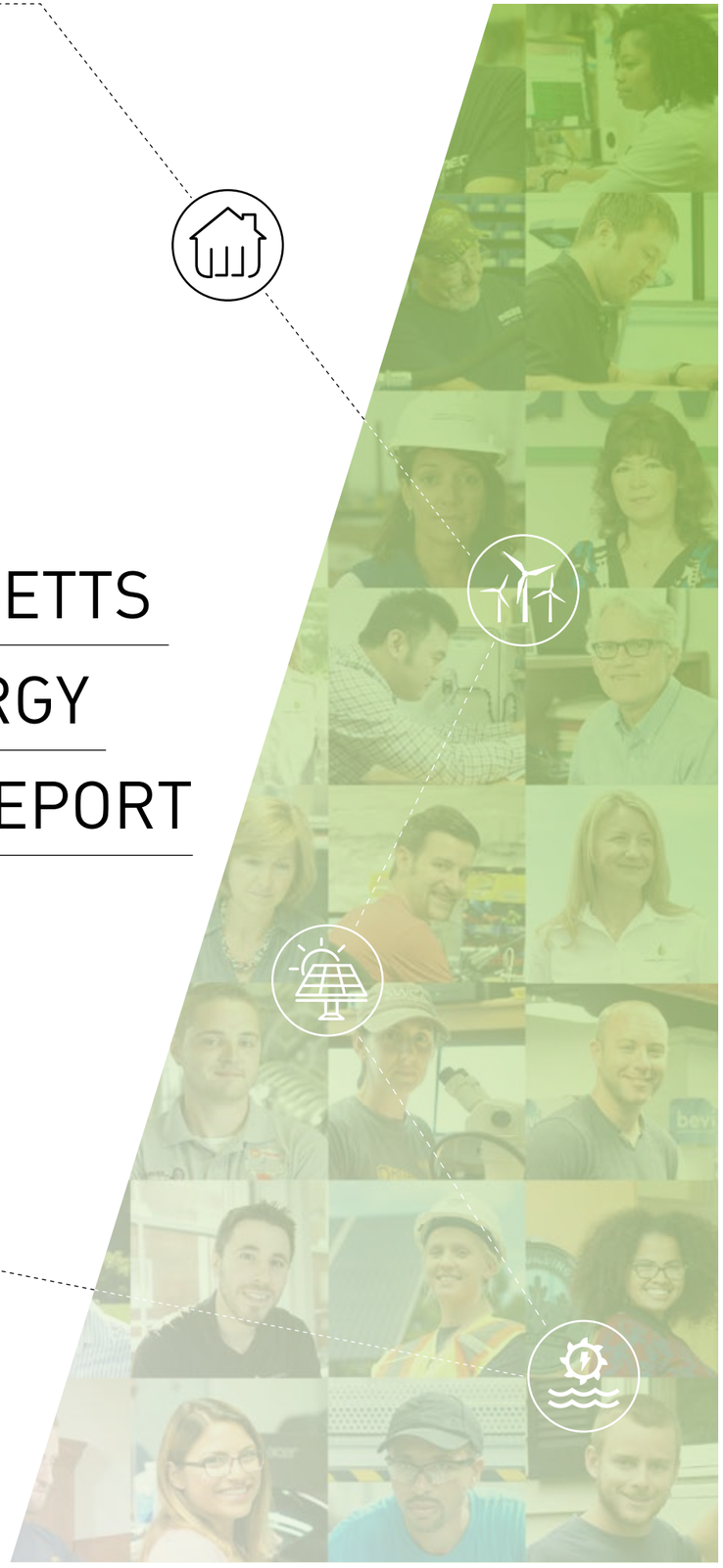

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MASSACHUSETTS CLEAN ENERGY CENTER

A Message from the CEO

Each year, the Massachusetts Clean Energy Center commissions an independent study to measure the development of the Commonwealth's clean energy industry, and this year marks the seventh consecutive year of clean energy industry growth in Massachusetts. According to the 2017 Massachusetts Clean Energy Industry Report, Massachusetts' clean energy industry reached more than 109,000 jobs statewide, an increase of 81 percent, or 49,000 jobs, since 2010.

Outpacing Massachusetts' 1.5 percent average statewide employment growth across all sectors, clean energy employment grew by 4 percent between 2016 and 2017. The clean energy sector has become an important part of the Massachusetts economy, contributing $11.4 billion in economic activity in the last year and accounting for 2.3 percent of Massachusetts' Gross State Product.

Consumer choice, business opportunity and the forward-thinking policies championed by the Baker-Polito Administration have fueled Massachusetts' transition to a cleaner, more resilient, more cost-effective renewable energy portfolio and have made the Commonwealth a national leader in clean energy. This year Massachusetts was named the most energy efficient state in the nation for the seventh year in a row, ahead of both California and New York and No. 1 in Bloomberg's 2017 Innovation Index.

To build on this momentum, MassCEC focused this year on delivering programs and services across the Commonwealth that focus on deployment, innovation and building supply chains to support emerging industries. In October, MassCEC released the Massachusetts Offshore Wind Ports and Infrastructure Assessment to help the offshore wind industry evaluate locations around the state that could be redeveloped to serve the nation's first commercial-scale offshore wind developments. In partnership with the Massachusetts Department of Energy Resources, we made the Commonwealth's first awards for energy storage, funding $20 million for 26 projects across the state. We broke records this year with our internship program, which has served 372 companies employing 2,522 students, resulting in over 430 full or part time hires since 2011. We also reaffirmed our commitment to increasing access to clean energy technologies for Massachusetts' low-and moderate-income residents, as we are projected to dedicate roughly $13.5 million dollars to this initiative this year.

Our report also reaffirmed that jobs in the clean energy industry pay well. Nearly 70 percent of Massachusetts' clean energy workers earn more than $50,000 – well above the state's overall median wage of $40,557.

Expanded employment and economic activity parallels a continued rise in the installation of renewable energy systems across the Commonwealth. Massachusetts' innovation sector continued to see strong results, as funding for early stage research and demonstration reached roughly $582.7 million between 2010 to 2016, even as funding for research at the federal level has declined. And the state's clean energy manufacturing sector grew steadily in 2017 at 8.6%, now employing 17,079 workers in the Commonwealth.

In the coming months, MassCEC will focus on investing in technologies and business models that aim to address our most pressing energy challenges. We're supporting emerging sectors such as offshore wind, microgrids, transportation, and energy storage while growing existing technology sectors like solar and clean heating and cooling.

Given the generational challenge of climate change at a time when leadership at the state level is paramount, our work has never been more vital and urgent. We are counting on your partnership to help us grow a sustainable, resilient and renewable energy economy for the benefit of all businesses and residents of the Commonwealth.

STEPHEN PIKE

CEO, Massachusetts Clean Energy Center

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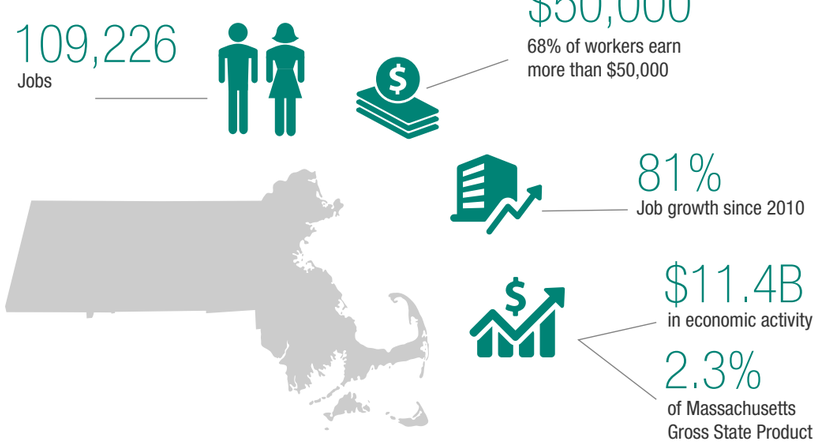
MassCEC's New Bedford Marine Commerce Terminal – a launching point for future offshore wind development

Executive Summary

Over the last seven years, the Massachusetts clean energy economy has continued to expand – growing at a faster pace year-over-year than the overall Massachusetts economy. Employment is growing, and companies are more focused on clean energy as their primary business endeavor. Activity is found across all segments of the value chain, with notable strength in research and development. With long-term policies and incentives in place, in-state clean energy deployment is strong, particularly for solar technologies. Massachusetts has also taken bold policy steps to continue that trend and increase deployment for offshore wind, clean heating and cooling, and energy storage technologies. The following are key findings from this 2017 Clean Energy Industry Report.

MASSACHUSETTS CLEAN ENERGY BY THE NUMBERS



Clean energy employment has grown for seven consecutive years. The clean energy economy again exceeded average statewide employment growth, as employment increased by four percent over the last year. With over 109,000 jobs in Massachusetts, the clean energy industry has grown by 81 percent since 2010. The sector also saw a 14 percentage point increase since 2011 in the number of firms who derive all of their revenue from clean technology goods and services, indicating that the clean energy economy is maturing as clean energy products and services become the primary source of revenue for more businesses.

Massachusetts leads on policy and market development. The Commonwealth was ranked the No. 1 state for effective energy efficiency policy and programs for the seventh consecutive year. The state also recently enacted legislation to diversify the Commonwealth's energy mix with commitments to offshore wind, hydroelectricity,

solar, and other renewable resources. Massachusetts is one of only three states nationwide with an energy storage procurement goal, again setting the pace for new clean energy technology implementation.

Massachusetts is home to a wealth of business development and innovation assets to support the creation and recruitment of clean energy businesses. Employers benefit from both policy support and the proximity to academic research institutions, investors, and global companies headquartered in the state. However, there is still opportunity to improve the clean energy talent pipeline. Clean energy employers still have challenges hiring employees, particularly for small businesses engaged in commercial installation and sales. The sector values experience, even for positions that the industry typically considers entry-level with relatively minimal educational requirements.

The Commonwealth continues to lead in clean energy innovation and research. Massachusetts outpaced California in 2017—on a per capita basis—for early-stage clean energy venture-backed investments. In fact, investments for the first two stages of innovation—research and demonstration—have shown recent upticks despite national uncertainties in federal research funding. Another indication of a strong research and development industry, clean energy-related patent and publication outputs continue to rise faster than the national average. However, private investments in Massachusetts' clean energy companies for the third innovation stage of commercialization have been on the decline.

Clean energy innovation has a big impact on the Massachusetts economy. Massachusetts clean energy innovators attracted $4.7 billion in direct investments between 2010 and 2016. Clean energy innovation activities contribute just over $34 million in state and local taxes. While only about four percent of clean energy employees work with pre-commercial products, this work supports an additional 5,450 jobs in Massachusetts. ■

Clean Energy Industry Overview

Clean Energy Employment

The Massachusetts Clean Energy Center (MassCEC) has tracked the size and growth of the state's clean energy economy since 2010. To date, clean energy companies employ just over 109,000 workers across 6,900 establishment locations.[1] The Bay State is home to approximately four percent of all clean energy workers across the nation,[2] and has more clean energy jobs per capita than Rhode Island and New York.[3]

For the past seven years, clean energy businesses have created jobs faster than the overall economy. Between 2010 and 2017, the clean energy workforce grew by 81 percent—roughly 49,000 additional jobs. Over the 12 month data collection period referenced for this report—July 2016 through July 2017—clean energy employment grew by four percent compared to a statewide average of just 1.5 percent over the same time; this translates to an additional 4,014 clean energy jobs since 2016 (Figure 1).[4] Consistent with previous year's reporting, most clean energy employment is concentrated in the energy efficiency, demand management, and clean heating and cooling sectors; together these total seventy-one percent of all clean energy jobs in 2017. The renewable energy sector created the most jobs since 2016, growing by 5.6 percent (Table 1).

Sixty-five percent of the state's renewable energy workforce—or 18,839 workers— is concentrated in the research, manufacturing, trade, or deployment of solar energy technologies; 12 percent are wind energy workers and the remaining 23 percent work with other renewable generation technologies such as hydropower and bioenergy. Massachusetts' solar workforce grew by 22 percent between 2015 and 2016 and by another four percent between 2016 and 2017, resulting in about 4,000 new jobs in two years. The recent slowdown in solar employment growth may be the result of industry maturation and restructuring, as solar companies shift their business models away from the residential market.[5]

Wind technologies employ about 3,400 individuals, 800 more workers compared to 2015 and just over 100 more workers than 2016. The wind sector is gearing up to see more activity, with the announcement of new offshore wind development projects and Massachusetts-based headquarters for Ørsted, Vineyard Wind, and Deepwater Wind. This increased activity is due to the nation-leading offshore wind procurement requirement of 1,600 megawatts (MW) as part of the Act Relative to Energy Diversity, which was passed by the Massachusetts Legislature and signed by Gov. Charlie Baker in 2016.

Energy efficiency jobs account for 62 percent of the energy efficiency, demand management, and clean heating and cooling technology sector. Most of these energy efficiency workers are engaged in weatherization services, energy-efficient building materials and appliances, and lighting fixtures. Clean heating and cooling accounts for 29 percent of the technology sector, with most workers supporting high efficiency air-source heat pumps, other efficient

HVAC and building controls, and woody biomass and pellet resources. The remainder of the sector, about 7,400 employees, is dedicated to grid modernization technologies such as storage, microgrid, smart grid, and demand response services. The state's alternative transportation firms are mostly engaged in supporting electric vehicles and the associated infrastructure, such as charging stations, followed by some activity in biodiesel for on-road vehicles.

A clean energy establishment is a business location with at least one employee. A clean energy firm or business organization (corporation, company, or partnership) can have multiple establishment locations.

FIGURE 1. CLEAN ENERGY JOBS, 2010-2017

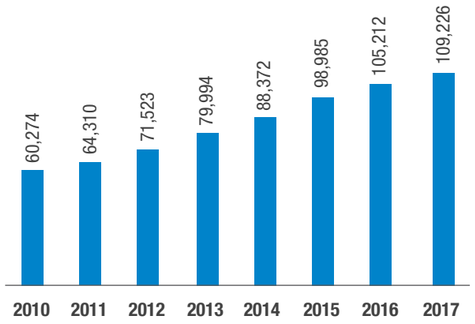
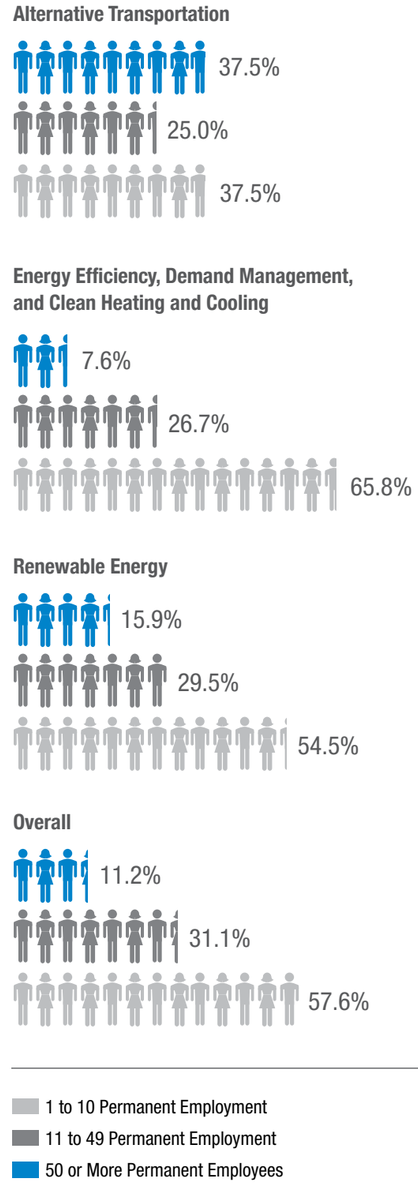


TABLE 1. CLEAN ENERGY JOBS AND ESTABLISHMENTS BY TECHNOLOGY, 2015-2017[6,7]

TECHNOLOGY	2015 Employees	2016 Employees	2017 Employees	2015 Establishments	2016 Establishments	2017 Establishments
Renewable Energy	23,658	28,769	28,988	2,113	2,334	2,395
Energy Efficiency, Demand Management, and Clean Heating and Cooling[8]	72,651	73,370	77,899	3,414	3,396	3,788
Alternative Transportation	1,478	1,740	1,761	467	482	426
Other	1,107	1,332	578	445	501	268
Total	**98,895**	**105,212**	**109,226**	**6,439**	**6,714**	**6,877**

The clean energy industry is comprised mostly of small business establishments employing between one to ten permanent employees. The distribution of clean energy establishments in the state shows that roughly 60 percent are small business locations, 30 percent are medium-sized, and 10 percent are large establishments with 50 employees or more; these results vary slightly by technology sector (Figure 2).

FIGURE 2. CLEAN ENERGY OVERALL FIRM SIZE BY TECHNOLOGY



In 2017, 48 percent of clean energy businesses attributed total revenue to clean energy activities. This increased from a reported 34 percent of firms in 2011. Over time, the Massachusetts clean energy economy has become increasingly concentrated with firms that are able to derive all their revenue from providing only clean energy goods and services.

In 2017, 82 percent of the clean energy workforce spent most of its time on clean energy business activities and 69 percent of workers spent all their time on clean energy work. This means that 74,600 clean energy workers spent all their labor hours on the research, trade, manufacturing, or deployment of clean energy goods and services. As with previous years, employment for this report captures all employees from qualifying clean energy firms that spend any portion of their time supporting clean energy-related work. However, workers may be considered either "full-" or "part-time" clean energy employees in order to better measure the degree to which firms are engaged in the clean energy market.

The sectors' demographics have remained steady, as the demographic distribution of the new hire pool closely matched that of the current workforce (Table 2). In 2017, 24 percent of clean energy workers were women, 12 percent were ethnic and racial minorities, 12 percent were over the age of 55, and five percent were Veterans of the Armed Forces.

TABLE 2. CLEAN ENERGY EMPLOYMENT DEMOGRAPHICS, 2016-2017[9]

	2016 Employment	2017 Employment	% of 2016 Workforce	% of 2017 Workforce	% of 2017 New Hires
Women	25,162	26,175	23.9%	24.0%	25.2%
Ethnic and Racial Minorities	12,199	12,677	11.6%	11.6%	11.9%
Veterans	5,574	5,787	5.3%	5.3%	5.3%
Workers over the age of 55	12,211	12,722	11.6%	11.6%	12.7%

The Clean Energy Value Chain

Massachusetts' clean energy work permeates all segments of the value chain. The clean energy value chain is a collection of activities and processes that together result in the creation and distribution of clean energy goods and services. Massachusetts has a robust in-state value chain that provides clean energy companies seeking to start, relocate, or expand their operations in the Commonwealth with access to vendors, engineers, and consultants. Recent policy announcements supporting the development of offshore wind and energy storage in the Commonwealth may spur activity in the clean energy value chain creating new opportunities and additional jobs.

The Commonwealth has a higher proportion of clean energy research and engineering workers compared to other Northeast clean energy economies like Vermont, Rhode Island, and New York.[10] Deployment activities, such as installation and sales, accounted for 54 percent of the clean energy workforce, or 58,400 workers in Massachusetts. While sales and distribution declined by just under two percent, the installation sector has grown by seven percent in 2017. With numerous academic research institutions, Massachusetts is also home to roughly 19,000 clean energy researchers and engineers and another 8,800 individuals that support the sector through consulting, finance, and legal services (Table 3). Compared to other nation-leading clean energy economies, Massachusetts is a global hub for clean energy research and development.

In 2016, clean energy goods and services contributed $11.4 billion, equivalent to 2.3 percent, to the Massachusetts Gross State Product (GSP). The manufacturing sector contributed the most to clean energy GSP, potentially due to the provision of goods to foreign markets outside of Massachusetts (Table 5). ■

TABLE 3. CLEAN ENERGY JOBS BY VALUE CHAIN, 2016-2017[11]

	2016	2017	2016-2017 Growth
Manufacturing	15,730	17,079	8.6%
Engineering & Research	18,196	19,034	4.6%
Sales & Distribution	29,194	28,749	-1.5%
Installation & Maintenance	27,617	29,639	7.3%
Professional Services (Consulting, Finance, Legal)	8,250	8,830	7.0%
Other	6,228	5,895	-5.3%

Percentage of 2017 Total

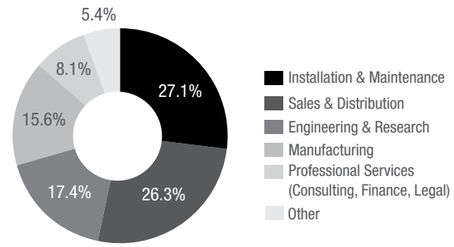
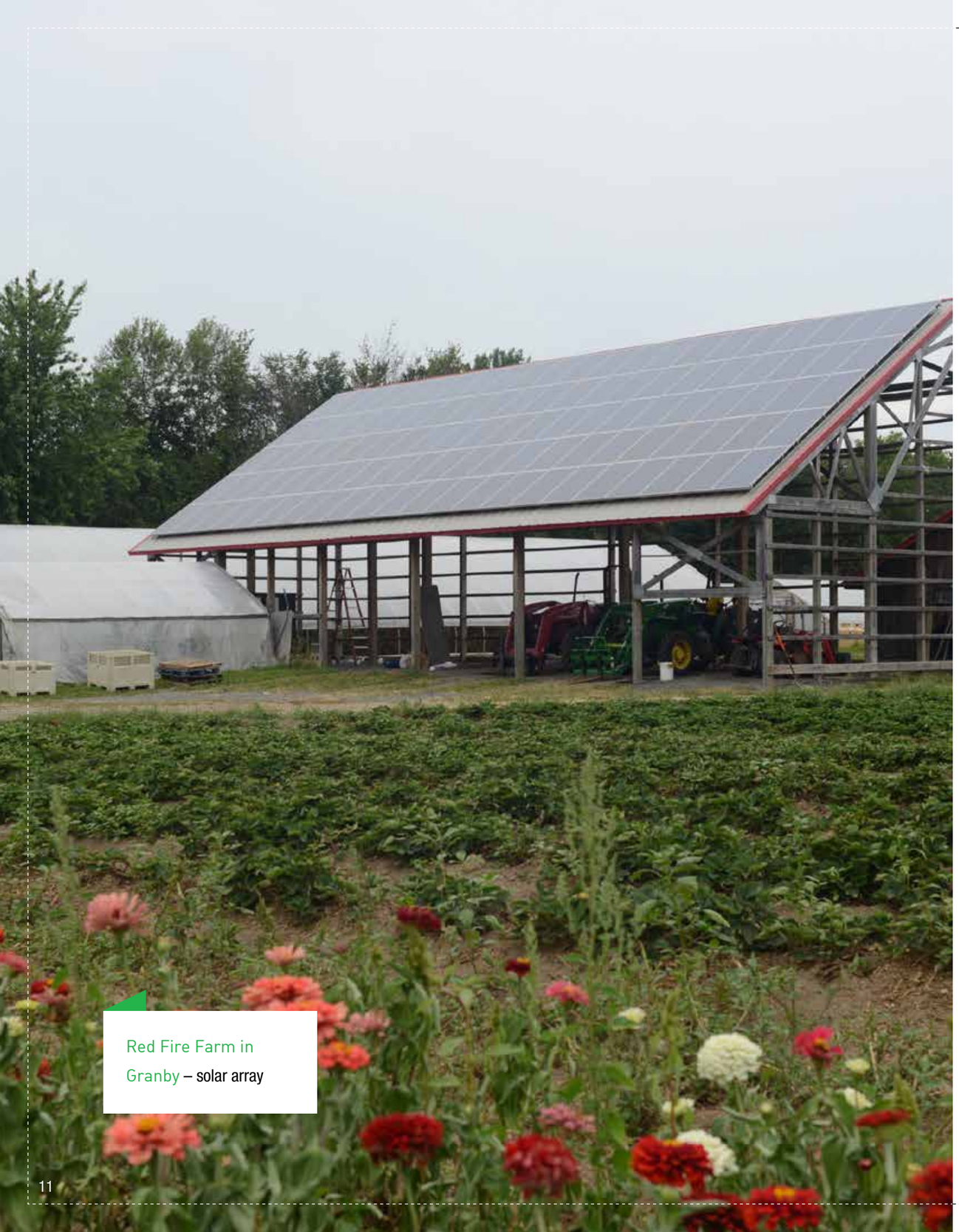


TABLE 4. VALUE CHAIN JOBS BY TECHNOLOGY, 2017[12]

	Manufacturing	Engineering & Research	Sales & Distribution	Installation & Maintenance	Professional Services
Renewable Energy	7,214	5,440	6,379	6,664	2,336
Energy Efficiency, Demand Management, and Clean Heating and Cooling	9,773	13,135	21,619	22,520	6,395
Alternative Transportation	46	347	673	181	41
Other	46	112	78	274	58
Total	**17,079**	**19,034**	**28,749**	**29,639**	**8,830**

TABLE 5. CLEAN ENERGY GROSS STATE PRODUCT (GSP) BY VALUE CHAIN, 2016[13]

	Gross State Product	% of Total Clean Energy GSP
Manufacturing	$3.4 billion	29.5%
Engineering & Research	$1.6 billion	14.1%
Sales & Distribution	$1.4 billion	12.7%
Installation & Maintenance	$1.9 billion	16.7%
Professional Services	$1.1 billion	9.9%
Other	$1.3 billion	11.4%
Sole Proprietors	$0.65 billion	5.7%
Total Clean Energy GSP	**$11.4 billion**	



Red Fire Farm in Granby – solar array

Clean Energy Deployment

Clean energy deployment continues to grow across all major technologies. Historical data for metrics such as installed capacity, program expenditures, rebates, and energy savings across the clean energy sectors in Massachusetts mirror the state's supportive policy climate. Overall, deployment for renewable energy technologies, energy efficiency, and alternative transportation has seen continuous annual increases over the past several years.

Renewable Electric Power Generation

Installed capacity under the Renewable Portfolio Standards (RPS) program in Massachusetts rose from just 41 megawatts (MW) in 2010 to over 506 MW in 2016, much of which can be attributed to solar power.[14] In 2016 alone, solar electric generation technologies accounted for 88 percent of new utility-scale generation capacity installed across Massachusetts.[15] From January through November 2017 there were 10,428 solar projects installed for 482 MW of capacity.[16]

In addition to the 1,600 MW solar mandate under the RPS, Governor Baker created The Solar Massachusetts Renewable Target Program (SMART)—a solar program that provides incentives for another 1,600 MW of solar generating capacity in the Commonwealth.[17] Additionally, Governor Baker signed legislation in 2016 that calls for 1,200 MW of a diverse array of other clean generation technologies, including hydropower, land-based wind, and other Class I renewable resources; the legislation also allows for the procurement of 1,600 MW of offshore wind.[18]

Energy Efficiency, Demand Management, and Clean Heating and Cooling

ENERGY EFFICIENCY

For the seventh consecutive year, Massachusetts held first place in the American Council for an Energy Efficient Economy (ACEEE) national Energy Efficiency Scorecard, recognizing that the state has the most effective energy efficiency policies and programs in the country.[19] In fact, per capita energy consumption in Massachusetts is low compared to other states, in part due to the state's comprehensive energy efficiency programs.[20] Since 2010, the MassSave program has almost doubled energy savings for electric utilities.[21] In January 2016, the Massachusetts Department of Public Utilities (DPU) approved new Three-Year Energy Efficiency Plans for electric and gas distribution companies. The plans include weatherization service programs, home energy service programs, codes and standards initiatives, and other new demand response offerings.[22]

Jay Moody Heating & AC – residential clean heating and cooling installation in Leominster

DEMAND MANAGEMENT: GRID MODERNIZATION AND STORAGE

In 2015, The Baker Administration launched the Energy Storage Initiative (ESI) with the goal of advancing the state's storage market for both utilities and distributed generation.[23] The Initiative is focused on:

- Accelerating the development of early-stage commercial storage technologies;
- Expanding markets for storage technologies and valuing storage benefits to clean energy integration, grid reliability, system-wide efficiency, and peak demand reduction; and
- Recommending and developing policies, regulations, and programs that help achieve these objectives.

Under the ESI, MassCEC and the Department of Energy Resources (DOER) sought proposals for energy storage demonstration projects as part of the Advancing Commonwealth Energy Storage (ACES) awards program. The program awards up to $1.25 million per project for the demonstration of the benefits of storage to Massachusetts ratepayers and the electric grid.[24] In addition, the Baker-Polito Administration announced a 200 MWh by 2020 energy storage deployment target to drive growth in the emerging storage sector.

CLEAN HEATING AND COOLING

In 2014, the DOER commissioned a report to advise the Department on which policies and programs the Commonwealth can deploy to grow the market for clean heating and cooling. The report identified six cornerstone strategies to promote clean heating and cooling development that include launching a comprehensive technology information campaign, supporting implementation of long-term performance based incentives, enabling low-cost financing, leveraging efforts across state agencies, and integrating clean heating and cooling into state buildings, public buildings, and the Stretch Energy Code. In 2014, the Massachusetts legislature authorized the inclusion of clean heating and cooling technologies in the state's Alternative Portfolio Standard (APS). Final rules for clean heating and cooling in the APS are expected in early 2018.[25]

Alternative Transportation

Alternative transportation is a small, emerging market within the clean energy sector, given the large greenhouse gas (GHG) emissions associated with transportation. In 2012, transportation contributed 41 percent of GHG emissions in the Commonwealth.[26] The Massachusetts Global Warming Solutions Act was created to achieve a 25 percent reduction of GHG emissions by 2020 and an 80 percent reduction by 2050 compared to 1990 levels.[27] In 2013, the Commonwealth signed the Multi-State Zero Emission Vehicle (ZEV) Memorandum of Understanding with a goal of having 300,000 ZEVs on the road in Massachusetts by 2025. Most recently, Governor Baker announced a Massachusetts Executive Office of Energy and Environmental Affairs (EEA) and Massachusetts Department of Transportation series of listening sessions to discuss solutions to the challenge of reducing greenhouse gas emissions from the transportation sector.

Massachusetts has seen increased numbers of electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV). In the first two quarters of 2017, a total of 2,256 zero emission vehicles were sold in Massachusetts, compared to 114 vehicles sold in all of 2011.[28]

Brighton-based XL Hybrids – electric vehicle

Clean Energy Innovation

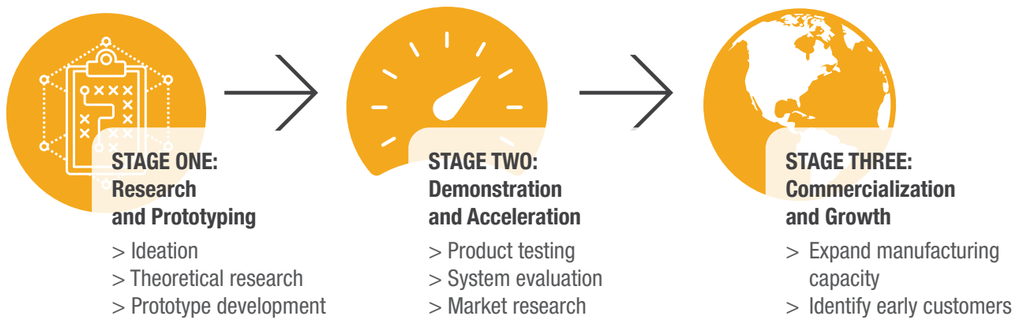
A robust innovation network is a key driver of the Massachusetts' clean energy industry. This year's innovation chapter tracks research and development activity using metrics like investment funding, public grants or awards, patent filings, and academic journal publications.

Massachusetts attracted a total of $4.7 billion in innovation funding between 2010 and 2016. Additionally, in 2017, Massachusetts outpaced California for early stage clean energy funding on a per capita basis.[29]

In addition to attracting investors that provide research funding, Massachusetts is also home to other assets that support clean energy innovation; these include academic institutions, research centers, incubators and accelerators, non-profits, and government organizations. Each region of the Commonwealth has a unique set of critical infrastructure that provides a support system for the state's clean energy inventors and entrepreneurs.

For the purposes of this report, the clean energy technology innovation process is broken into three key segments: 1) Stage I: Research and Prototyping; 2) Stage II: Demonstration and Acceleration; and 3) Stage III: Commercialization and Growth.

FIGURE 3. THE STAGES OF INNOVATION



Stage I: Research and Prototyping

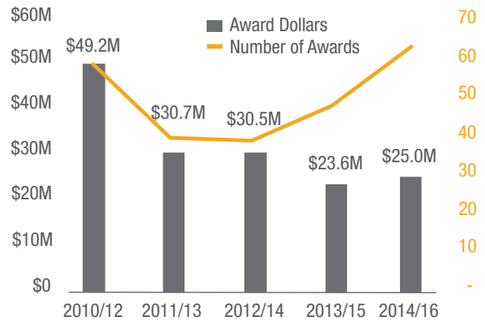
Early-stage research funding in Massachusetts increased six percent - from $23.6 million to $25 million over the latest three-year rolling averages between 2013 and 2016. The total number of grants continued to increase much faster than dollar amounts, indicating that average award size has declined over time (Figure 4). However, the slight rebound in funding for this stage is promising since federal research investments from nearly all major agencies, including the U.S. Department of Energy (DOE), have been declining across the nation for several years. Between 2014 and 2015, DOE research and development expenditures decreased by five percent.[30]

In general, federally-funded research initiatives have declined, while funding from universities, nonprofits, businesses, donations, and other non-public sources have increased. Overall university expenditures increased by two percent between 2015 and 2016, and these non-federal dollars have been able to partially offset the decline, particularly for research in the engineering, environmental, and physical sciences. Of the top 30 higher education research and development institutions across the nation for fiscal year 2015, Harvard University and Massachusetts Institute of Technology saw research expenditures increase by nine and three percent respectively between 2014 and 2015.[31]

While university research does not have high direct employment contributions to the economy, the economic multipliers associated with research activities created an additional $55 million in wages, $4.8 million in state and local taxes, and supported an additional 850 jobs throughout the value chain.[32]

Patent activity has been mostly steady with a slight decline over the last couple of years.[33] Nationally, clean energy patent production saw greater declines between 2015 and 2016 compared to Massachusetts. The state's patent activity has been more heavily concentrated in renewable electric power generation with little alternative transportation activity compared to the national average. Peer-reviewed publications are another indicator of innovative activity, demonstrating academic, technical, and scientific talent in the region. Clean energy publications in Massachusetts continued to grow over the last six years, faster than the national averages.[34] In fact, seven percent of all clean energy-related academic articles are from Massachusetts.

FIGURE 4. CLEAN ENERGY INVESTMENTS: STAGE I, 2010-2016 (THREE-YEAR ROLLING AVERAGES)[35]

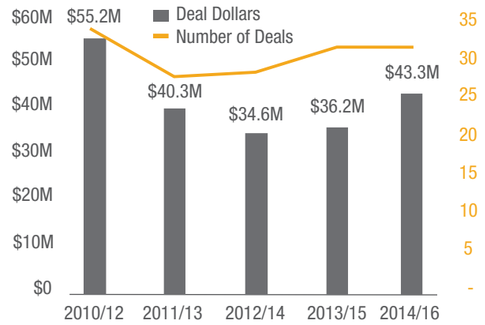


Stage II: Demonstration and Acceleration

Investments in the demonstration and acceleration stage have also seen a slight rebound, as companies recently secured the most investment dollars since their peak in 2010. Total funding increased by almost 20 percent between the latest three-year rolling averages—from $36 million to $43 million (Figure 5). This funding is driven both by public and private capital. This stage includes Seed and Series A funding from private companies, as well as some Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), SunShot, and MassCEC grants awarded to companies.

Approximately 1,200 researchers and engineers are working with technologies in the demonstration and acceleration stage. These research activities had a significant impact on the economy, creating more than $90 million in additional wages and $9.4 million in state and local taxes, while supporting an additional 1,500 jobs across the Commonwealth.[36]

FIGURE 5. CLEAN ENERGY INVESTMENTS: STAGE II, 2010-2016 (THREE-YEAR ROLLING AVERAGES)[37]

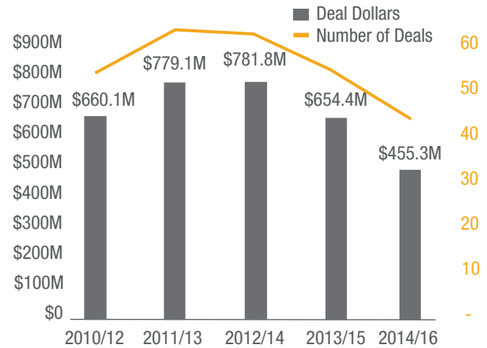


Stage III: Commercialization and Growth

Overall, late-stage commercialization funding has been much higher in total dollars over the last six years compared to the research and demonstration phases. Funding dollars, however, have continuously declined since the high in 2012. Companies that reached this stage received a total of $4.1 billion between 2010 and 2016, compared to just $254.9 and $327.8 million, respectively, for stages one and two.[38] However, recent trends are not as promising as the early-stage research or demonstration phases. Over the latest two three-year rolling averages, late-stage commercialization and growth funding declined by 30 percent from $654.4 million to $455.3 million (Figure 6). This is similar to national trends, where investments in this stage declined by about 20 percent over the same time frame.[39] Unlike stages one and two, the final phase of innovation is comprised of very little government funding. Typically, the private sector takes over to bring new technologies to market once they have reached maturity. However, regulatory and market barriers sometimes keep good technology on the sidelines; this market gap can be an impediment to emerging clean energy technologies.

Approximately 2,500 researchers and engineers worked in the commercialization and growth stage in 2017. These activities, and the $455 million of foreign capital they attracted on average on an annual basis from 2014 to 2016, created an additional $200 million in wages and nearly $20 million in state and local taxes, while supporting an additional 3,100 jobs in Massachusetts.[40]

FIGURE 6. CLEAN ENERGY INVESTMENTS: STAGE III, 2010-2016 (THREE-YEAR ROLLING AVERAGES)[41]



East Boston Umana Academy – students participating in MassCEC's Clean Energy Activity Day

Clean Energy Talent

Employers, in particular small businesses, lack a robust pipeline of qualified employees and report hiring difficulties. In 2017, clean energy employers reported similar levels of difficulty finding talent when compared to previous years. About 25 percent of establishments report that finding talent is very difficult, with just over 50 percent saying it is somewhat difficult (Figure 7).

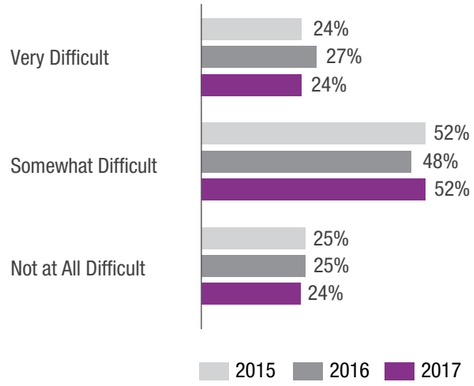
Seventy-two percent of small business employers indicated that finding qualified candidates was difficult over the report survey period, with 30 percent noting it was very difficult. Firms that work primarily with commercially available products reported greater hiring difficulty compared to those working with pre-commercial products by about eight percentage points, suggesting that the clean energy sector has a larger supply of researchers and engineers, but fewer solar installers, technicians, building inspectors, or electricians.

In 2017, 53 percent of clean energy new hires were for experienced positions as opposed to entry-level work.

The most frequently cited reasons for hiring difficulty were related to candidates' lack of industry-specific technical skills and insufficient work experience (Figure 8).

In 2017, about 45 percent of clean energy workers had either a high school diploma or post-graduate credential, but not a college degree (Figure 9). These individuals are typically those engaged in installing new technologies and building upgrades.

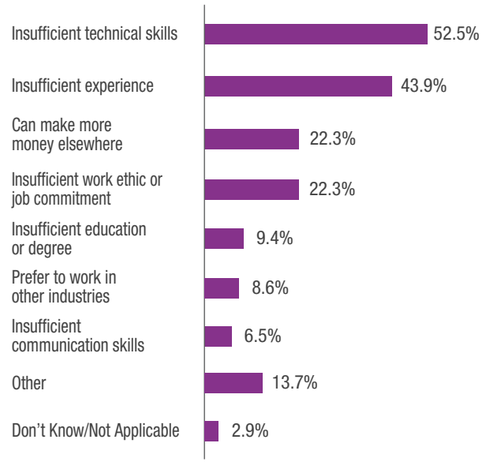
FIGURE 7. HIRING DIFFICULTY, 2015-2017



Experienced clean energy workers are in high demand, even for what are typically considered entry-level positions with lower educational requirements.

FIGURE 8. REASONS FOR HIRING DIFFICULTY, 2017

Employers note that many candidates fall into the following categories, which lead to hiring challenges.



Boston Cleanweb Hackathon – participants collaborating on technology pitches

FIGURE 9. CLEAN ENERGY EDUCATIONAL ATTAINMENT, 2015-2017

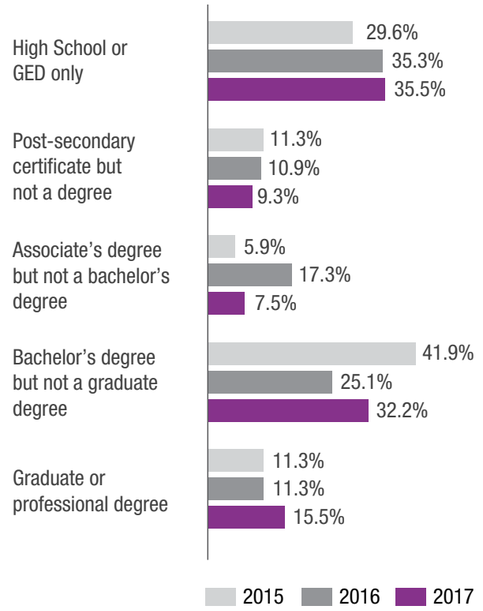
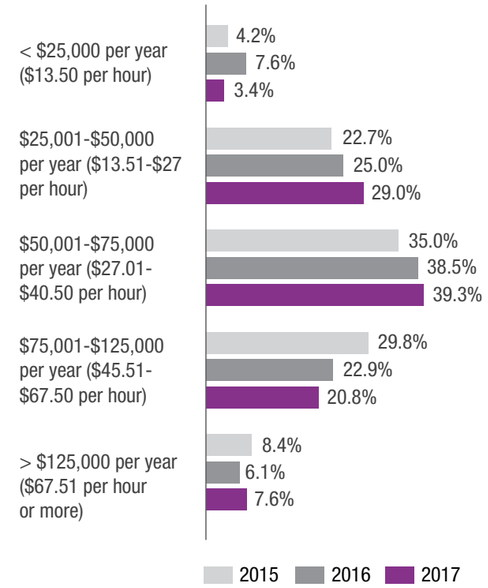


FIGURE 10. CLEAN ENERGY WAGES, 2015-2016



Clean energy jobs provide a sustainable source of income for Massachusetts' residents. According to the Massachusetts Institute of Technology's Living Wage Calculator, the minimum living wage in Massachusetts for a dual income household with two children is approximately $62,000 per year, assuming each working adult earns about $31,000 a year.[42] About sixty-eight percent of clean energy employers reported that they pay their employees more than $50,000 per year, and about twenty-eight percent indicated that they pay more than $75,000 per year (Figure 10). ■

Regional Highlights

The Commonwealth has numerous statewide and regional clean energy innovation assets, including, but not limited to, research institutions, incubators as well as business accelerators and technology competitions. See Figure 11 for a subset of the statewide innovation assets available to the clean energy ecosystem. In addition, each region of the Commonwealth is home to its own unique set of innovation assets – ranging from academic institutions to R&D facilities – which are vital to the support and growth of the clean energy industry (Figure 12).

Clean energy employment is concentrated in northeastern Massachusetts, with technology strengths varying by region. Northeast Massachusetts, which includes Boston, accounted for 48 percent of total clean energy employment in 2017. The southeastern portion of the state accounted for 24 percent of clean energy employment, with the western and central regions of the state accounting for approximately twelve and seventeen percent of clean energy employment, respectively. Nearly all regions, with the exception of central Massachusetts, saw employment grow by at least three percent over the survey period. Southeastern Massachusetts outpaced other regions by growing clean energy jobs at a rate of almost six percent.

The northeast possesses the majority of employment regarding renewable energy generation, with 73 percent of the state's entire renewable energy workforce. Energy efficiency work was more evenly spread across the state, however, with most energy efficiency workers—69 percent— concentrated in northeastern and southeastern Massachusetts.

FIGURE 11

Featured Statewide Innovation Assets

- ACTION Association of Cleantech Incubators of New England
- Cleantech Open Northeast
- Massachusetts Clean Energy Center
- MassCEC Wind Technology Testing Center
- MassChallenge
- MIT Clean Energy Prize
- MIT Energy Initiative
- Northeast Clean Energy Council
- TechStars
- TiEScale Up
- Venture Well

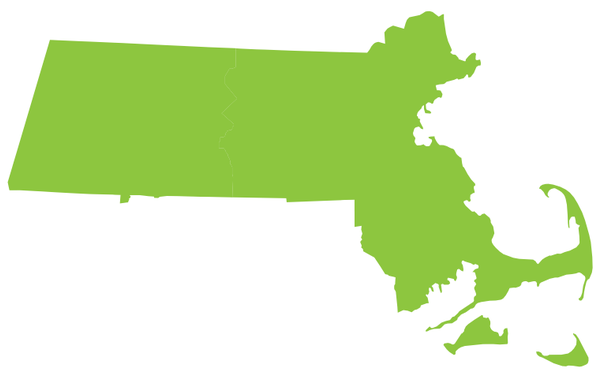
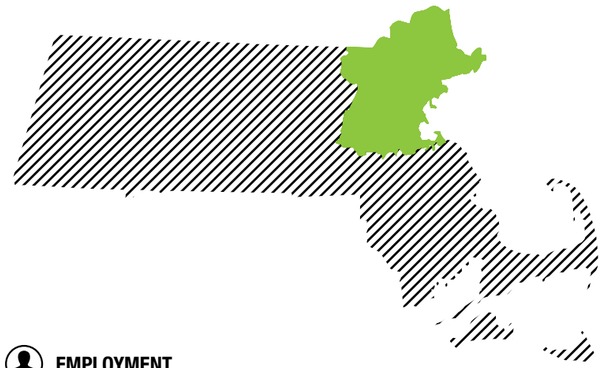


FIGURE 12[43]

Northeast Region

FEATURED INNOVATION ASSETS

- Boston University
- Cambridge Innovation Center
- CI Works
- Draper Labs
- Fraunhofer CSE
- Greentown Labs
- Harvard University
- Mass Robotics
- Massachusetts Institute of Technology
- MIT Engine
- MIT Lincoln Labs
- Northshore Innoventures
- Tufts University
- University of Massachusetts Boston
- University of Mass Lowell



EMPLOYMENT

2015	2016	2017	% of Total 2017	Growth 2016-2017
46,626	50,712	52,520	48.1%	**3.6%**

ESTABLISHMENTS

2015	2016	2017	% of Total 2017	Growth 2016-2017
2,929	3,012	3,089	44.9%	**2.5%**

Central Region

FEATURED INNOVATION ASSETS

- Alden Labs
- National Grid Test Lab
- Worcester Cleantech Incubator
- Worcester Polytechnic Institute

EMPLOYMENT

2015	2016	2017	% of Total 2017	Growth 2016-2017
17,530	17,900	18,041	16.5%	**0.8%**

ESTABLISHMENTS

2015	2016	2017	% of Total 2017	Growth 2016-2017
1,005	1,051	1,081	15.7%	**2.9%**

Southeast Region

FEATURED INNOVATION ASSETS

- Bristol Community College
- Center for Innovation and Entrepreneurship-University of Massachusetts Dartmouth
- Massachusetts Alternative Septic System Testing Center
- New Bedford Marine Commerce Terminal
- Wood Hole Oceanographic Institute

EMPLOYMENT

2015	2016	2017	% of Total 2017	Growth 2016-2017
22,431	24,266	25,706	23.5%	**5.9%**

ESTABLISHMENTS

2015	2016	2017	% of Total 2017	Growth 2016-2017
1,472	1,636	1,668	24.3%	**2.0%**

Western Region

FEATURED INNOVATION ASSETS

- Greenfield Community College
- Lever
- Massachusetts Green High Performance Computing Center
- Northeast Sustainable Energy Association
- Springfield Innovation Center
- University of Massachusetts Amherst
- Valley Venture Mentors
- Western Massachusetts Economic Development Council

EMPLOYMENT

2015	2016	2017	% of Total 2017	Growth 2016-2017
12,308	12,335	12,958	11.9%	**5.1%**

ESTABLISHMENTS

2015	2016	2017	% of Total 2017	Growth 2016-2017
931	1,014	1,038	15.1%	**2.4%**

Appendix A:

Methodology and Data Sources

Introduction

This report details the core elements of the Massachusetts clean energy industry and its key features through the analysis of (a) public data, such as federal and state labor market data, Census Bureau data, and input-output information from the Bureau of Economic Analysis; (b) proprietary data sources such as business listings from Dun & Bradstreet and InfoUSA; (c) investment and patent information from Cleantech Group's i3 platform; and, (d) primary data collection from clean energy employers across the Commonwealth.

Clean Energy, while defined by the Massachusetts Legislature (MGL 23J), does not have a consistent definition across states and nations, nor does it have a dedicated, well-defined set of North American Industry Classification System ("NAICS") codes associated with it. This report has adopted a definition for "clean energy" consistent with MGL 23J.

Since existing data frameworks do not provide meaningful insight into clean energy trends on their own, primary data, collected directly from employers, serve as a necessary substitute to ensure the accurate development of clean energy-specific metrics including employment and establishment totals.

As with previous years' editions of the Clean Energy Industry Report, some of the primary data included in this study derives from a comprehensive survey of business establishments in Massachusetts. The survey is conducted on a random sample of businesses and results are extrapolated to the entire universe. Details on the survey are presented below.

The research methodology employed for this report, including the survey instrument and sampling plan, has been reviewed and accepted by the Department of Energy and Bureau of Labor Statistics. It has been used by the U.S. Government in its annual Energy and Employment Report, and has been used increasingly as a tool for measuring clean energy industry jobs and establishments across multiple states, including in California, Florida, Illinois, Iowa, Missouri, Ohio, Pennsylvania, Rhode Island, Tennessee, and Vermont.

For a comprehensive list of definitions, please refer to the glossary in Appendix B.

Data Sources

GROSS STATE PRODUCT (GSP) AND REVENUES DATA

GSP is also presented both for the overall clean energy economy and each of the four major technologies; the data supports the economic index portion of each of the BW Indices and is presented through the second quarter of 2017. The input-output data for GSP is derived from data from the U.S. Bureau of Economic Analysis. Gross State

Product (GSP) is an important measure of economic activity, measuring the value and flow of goods and services produced in the economy. Any reported revenue data is collected through the employer survey.

Gross State Product is calculated using data from the Bureau of Economic Analysis, by NAICS code. Each NAICS industry's Gross State Product is multiplied by the ratio of clean energy establishments to all establishments within the NAICS segment. This produces the Gross State Product contribution of establishments engaged in clean energy activities. To generate the clean energy proportion, this figure is further reduced by multiplying it by the mean reported revenues attributed to clean energy goods and services from the survey.

JOBS AND ESTABLISHMENTS DATA

Jobs and establishments data are collected from federal data sources, state data sources, and employer surveys. Survey data references the 12 months falling within July 2016 through July 2017. The federal sources used include the Bureau of Labor Statistics' Quarterly Census of Employment and Wages, Current Employment Statistics, and Occupational Employment Statistics, which are all available publicly at http://bls.gov. This report uses state data provided by the Massachusetts Executive Office of Labor and Workforce Development.

INVESTMENT CAPITAL/ INNOVATION DATA

This report uses Cleantech Group's i3 Platform for all investment data. The i3 data platform was selected for this analysis since every investment included in the database is independently cited and can be verified, unlike many reports that do not disaggregate the data. The Platform is a comprehensive catalogue of innovative clean energy companies worldwide; datasets can be filtered by technology, investment type, geography, and time frame. The data reported indicate both total dollar amounts and deals—which refers to the number of single investments closed.

As with previous years, this report includes only "new energy" investments, which contrasts with some other studies on clean energy investment trends. Most of those reports, including Bloomberg New Energy Finance Reports, are heavily influenced by asset finance deals. Unfortunately, asset finance is not further delineated between new project financing and existing entity debt restructuring or other business lines of credit not focused on new energy. In clean energy markets, project finance typically is used for new energy production rather than for restructuring existing energy projects. Only investments to private equity-backed establishments are included in this report.[44]

The i3 data include a wide range of investment types, as well as technologies that are outside of the scope of this report. As a result, Cleantech Group's publicly reported data will differ from the results included in this report. For the purposes of this study, the following filters were applied:

Investment Type: Early-stage (Seed, Series A, Series B), Structured Debt, Growth Equity, Project Finance, Grants, Loans, and Guarantees

Technologies: Energy Efficiency and Building Envelope (e.g., lighting, energy efficient appliances, energy efficient processes and machinery, weatherization services, energy efficient building materials, water and wastewater technologies related to conserving energy); Energy Storage (e.g., fuel cells/hydrogen, solid state batteries, flow batteries, flywheels, compressed air energy storage, thermal, pumped hydro-power); Grid Modernization and Demand Response (e.g., smart grid, smart computing/ software, demand response services, micro-grids); Renewable Energy for Electrical Power Generation (e.g., solar, offshore wind, onshore wind, river/wave/tidal hydropower, bioenergy, landfill gas, biogas, anaerobic digestion, woody biomass); Renewable and Efficient Heating and Cooling (e.g., solar thermal, high efficiency air-sourced heat pumps, efficient HVAC/building controls, ground-sourced heat pumps, woody biomass, biodiesel, RE combined heat/power); Alternative Transportation (e.g., electric vehicles and systems, charging stations, biodiesel for on-road vehicles)

Submitted i3 data was reviewed by MassCEC staff and was complemented with the following datasets: ARPA-E, SBIR/ STTR awards from the Department of Energy, MassCEC grants, and the SunShot Initiative.

PATENT AND PUBLICATION DATA

This report uses patent and publication data filings from Clarivate Analytics: data spanning the period of 2010 to 2016. Specifically, this report used Clarivate's patent and publication research intelligence service brand called "Derwent Innovation". The service's patent data are sourced from the World Intellectual Property Organization (WIPO), European Patent Office (EPO), and United States Patent and Trademark Office (USPTO), while publication data are extracted from an array of trusted, scientific literature sources that include Web of Science, Current Contents Connect, Conference Proceedings, and Inspec. The firm's combined data solutions are trusted to give the most comprehensive monitoring of technology trends and competitive landscapes, informing of Freedom to Operate (FTO) opinions, prosecuting of patents, and monetizing/ licensing of assets and supporting litigation activities to date.

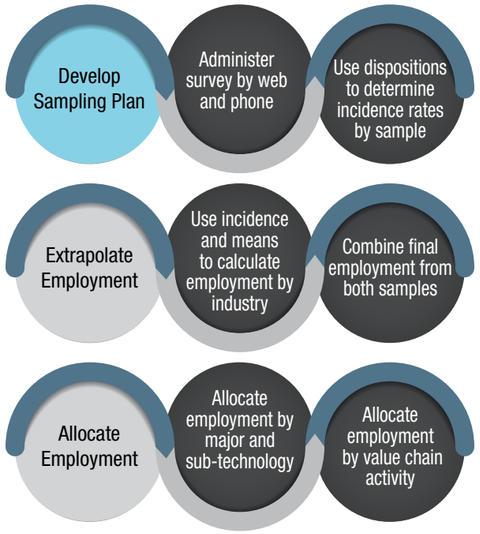
This platform does not yet provide disaggregated patent and publication information by subtechnologies. As a result, all patent and publication data totals referenced in the report illustrate total patent activity of all subtechnologies in a major category. For the purposes of this study, the following subtechnology filters were applied:

Technologies: Energy Efficiency and Building Envelope (e.g., lighting, energy efficient appliances, energy efficient processes and machinery, weatherization services, energy efficient building materials, water and wastewater technologies related to conserving energy); Energy Storage (e.g., fuel cells/hydrogen, solid state batteries, flow batteries, flywheels, compressed air energy storage, thermal, pumped hydro-power); Grid Modernization and Demand Response (e.g., smart grid, smart computing/ software, demand response services, micro-grids); Renewable Energy for Electrical Power Generation (e.g., solar, offshore wind, onshore wind, river/wave/tidal hydropower, bioenergy, landfill gas, biogas, anaerobic digestion, woody biomass); Renewable and Efficient Heating and Cooling (e.g., solar thermal, high efficiency air-sourced heat pumps, efficient HVAC/building controls, ground-sourced heat pumps, woody biomass, biodiesel, RE combined heat/power); Alternative Transportation (e.g., electric vehicles and systems, charging stations, biodiesel for on-road vehicles)

In addition, because of the highly technical nature of the patents, all patents awarded to establishments that identify as working in clean energy are counted, whether or not the patents are directly related to clean energy technologies.

EMPLOYER SURVEY METHODOLOGY

FIGURE 13. SURVEY METHODOLOGY FLOW CHART



Surveys were administered online and by telephone to a list of known employers, as well as to a representative, clustered sample of companies from the NAICS system identified by the Bureau of Labor Statistics (BLS) and BW Research Partnership as being potentially related to the Renewable Energy, Energy Efficiency and Alternative Transportation technologies.

The surveys were developed using industry associations, data from past years, and other proprietary sources.

The survey used a stratified sampling plan (Figure 13) that is representative by industry code (NAICS or ANAICS), establishment size, and geography to determine the proportion of establishments that work with specific clean energy-related technologies, as well as the proportion of workers in such establishments that work with the same. These data are then analyzed and applied to existing public data published by the Bureau of Labor Statistics, effectively constraining the potential universe of energy establishments and employment. It is important to note, this report excludes any employment in retail trade NAICS codes—fueling stations, fuel dealers, motor vehicle dealerships, appliance and hardware stores, and other retail establishments.

The survey was administered by telephone (14,970 outbound calls to about 10,250 unique companies) and by web, with 1,540 emails sent to participants across the Commonwealth. The phone survey was conducted by I/H/R Research Group and Castleton Polling Institute. The web instrument was programmed internally by BW Research employees and each respondent was required to use a unique ID to prevent duplication. Of the 10,250 companies contacted, 1,358 business establishments participated in the survey effort, with 396 providing full responses to the survey. Over the last three years, there have been a total of nearly 1,500 full responses to the survey.

These responses were used to develop incidence rates (the proportion of clean energy establishments within traditional industries) as well as to apportion employment across various industry categories in ways currently not provided by state and federal labor market information agencies. The margin of error for incidence is +/-2.60% at a 95% confidence interval. The survey fielded from June 15 to July 14 and averaged 14 minutes in length. As such, data gathered from the survey refers to the 12 months between July 2016 through July 2017.

Margin of error is dependent on responses, universe size, and confidence interval is the width of error allowed within that. Ninety-five percent is the most commonly used confidence interval in polling; this means that the researchers have a 95 percent statistical confidence that the "true" result is within the margin of error. While the margin of error can change based on metrics, confidence interval does not—the margin of error is always reported with the confidence interval used for calculation.

In addition to providing overall totals, survey respondents were asked to select the technology to which their work is most closely associated: (1) Renewable Electrical Generation, (2) Renewable and Efficient Heating and Cooling, (3) Energy Efficiency and Building Envelope, (4) Grid Modernization and Demand Response, (5) Storage, (6) Alternative Transportation, or (7) Other. Based on their selection(s), respondents were offered lists of specific sub-technologies that fit within each technology.

Establishments in manufacturing and research, design, and engineering were asked a specific question about whether they worked with any goods that are not yet commercially available, to gain insight into how research, development, and engineering startups and other early-stage, pre-commercial establishments might respond differently to survey questions from other established firms with commercially available products.

The sample was split into two categories.[45] The first category includes establishments that have been previously identified as clean energy-related, either in prior research or some other manner, such as membership in an industry association or participation in government programs. These establishments were surveyed census style, and their associated establishment and employment totals were removed from the second category (see below) for both sampling and for resulting employment calculations and estimates. The second category includes an accounting of tens of thousands of businesses in potentially clean energy-related NAICS codes across agriculture, utilities, construction, manufacturing, wholesale trade, professional services, and repair and maintenance. Each of these segments and their total reported establishments (within the Bureau of Labor Statistics QCEW) were carefully analyzed to develop representative clusters for sampling.

All data in the index rely on the Bureau of Labor Statistics Quarterly Census of Employment and Wages data for the fourth quarter of 2016.

Establishments Previously Identified by Researchers as Clean Energy Companies (Known Universe)

At the outset of the 2017 report's development, MassCEC provided an annual "known" database of firms, which included 2,207 entries. This list contained addresses and phone numbers for clean energy establishments and other organizations (and individuals) in the Commonwealth of Massachusetts. The list included some individuals and system owners, and as a first step BW Research cleaned and removed duplicates from the original list. Specifically, BW Research removed foreign corporations, obvious individuals, and duplicate entries, as well as companies that were asked to be placed on a DNC (do not call) list in previous years. The next step was to add additional records from MassSave and various local and national industry associations (Northeast Clean Energy Council, American Wind Energy Association, etc.). After completing the merge, BW Research conducted additional cleaning and de-duplication of the list, resulting in a final total of 1,812 baseline industry contacts established as the "known universe."

All establishments in the database with addresses were sent a letter with respondent-specific instructions for taking the survey. In addition, all businesses with email information were sent multiple online invitations. Establishments in the database that did not complete an online survey and those without email information were called up to five times and asked to complete the survey by telephone.

ESTABLISHMENTS NOT PREVIOUSLY IDENTIFIED BY RESEARCHERS AS CLEAN ENERGY COMPANIES (UNKNOWN UNIVERSE)

BW Research, in coordination with the U.S. Department of Energy and independently with several states (including Massachusetts), has developed a list of 93 six-digit NAICS codes that are likely to contain clean energy establishments. These NAICS include 30,131 establishments in Massachusetts and about 331,469 workers. Importantly, the unknown universe excludes academic research centers, nonprofit organizations, and sole-proprietors. The establishments and employment calculated for the known universe within each NAICS is subtracted from the NAICS totals and contacts are de-duplicated, meaning that there is no overlap between the known and unknown universes.

Surveys were administered in accordance with the Code of Standards and Ethics for Survey Research (CASRO), which includes stringent guidelines for maintaining respondent confidentiality. As a result, employer lists and disaggregated data are not available for public release.

Appendix B: Glossary of Terms

Activity: For the purposes of this report, an establishment's activity refers to the primary value-chain industry to which it most associates its work. Activities include research, development and engineering, manufacturing, sales and distribution, installation and maintenance, legal, finance, and other professional services, and other.

Clean Energy Industry: The aggregate of establishments that are directly involved with researching, developing, producing, manufacturing, distributing or implementing components, goods or services related to Renewable Energy, Energy Efficiency or Conservation, Smart Grid, Energy Storage, Carbon Management and/or Electric or Hybrid Vehicles.

Clean Energy Establishment: For the purposes of this report, an establishment is any establishment that is involved with an activity related to the clean energy industry.

Clean Energy Worker: Full-time and part-time permanent employees who support the clean energy portion of the business, including administrative staff, excluding interns and other temporary workers.

Establishment: For the purposes of this report, a business location in Massachusetts with at least one employee.

Firm: A business organization, such as a corporation, company, or partnership. A firm can have multiple establishment locations.

Pre-commercial: Work that has yet to reach market or products that are in the development phase.

Professional Service: Any sort of finance, legal, architecture, or other mathematical or scientific services that support clean energy technology development and deployment.

Sub-technology: For the purposes of this report, sub-technology refers to the specific technologies with which an establishment works, within each technology area. The sub-technologies for Energy Efficiency and Renewable Energy are listed under the respective definitions.

Technology: For the purposes of this report, technology refers to the primary application or end-use of an establishment's produced goods or services.

Gross State Product: The clean energy portion of Gross State Product calculated for this report was derived from survey incidence rates and proportional revenue reporting, together existing data from the Bureau of Economic Analysis, calculated by NAICS code. Utility-data and state government spending were included as direct inputs (rather than using a proportional analysis).

Appendix C: Citations

1 A clean energy establishment is a business location with at least one employee. A clean energy firm or business organization (corporation, company, or partnership) can have multiple establishment locations.

2 Environmental Entrepreneurs (E2). Clean Jobs America, March 2016.

3 Rhode Island Office of Energy Resources. Rhode Island Clean Energy Industry Report, 2017; and, New York State Energy Research and Development Authority (NYSERDA), New York Clean Energy Industry Report, 2017.

4 Bureau of Labor Statistics. Current Employment Statistics. July 2016 – July 2017. Extracted on August 10, 2017.

5 Pyper, Julia. US residential solar market forecast to decline for the first time. Greentech Media (GTM), September 2017.

6 The decline in "other" employment is largely the result of improved methodology that resulted in better classification of clean energy workers into their appropriate technology category.

7 Granular employment and establishment data that disaggregates by technology may not sum to high-level numbers due to rounding.

8 This technology sector also includes grid modernization and storage sub-technologies.

9 The 2016 proportion will differ from last year's report due to a revised methodology. The 2017 survey data allowed for more granular analysis weighted by value chain, producing a more reliable average for the overall clean energy economy as each segment—manufacturing, installation, research, etc.—differs in terms of demographic distributions. The new hire analysis by value chain for 2017 was applied to 2016 employment data to generate an estimate for 2016 proportions.

10 Rhode Island Office of Energy Resources. Rhode Island Clean Energy Industry Report, 2017; Vermont Clean Energy Development Fund and Department of Public Services. Vermont Clean Energy Industry Report, 2017; and, New York State Energy Research and Development Authority (NYSERDA), New York Clean Energy Industry Report, 2017.

11 The decline in "other" employment is largely the result of improved methodology that resulted in better classification of clean energy workers into their appropriate value chain activity.

12 Granular employment data that disaggregates value chain jobs by technology may not sum to high-level numbers due to rounding. For example, the professional services column in Table 4 totals to 8,829, but when using all decimal places, employment totals to 8,830 per the high-level number reported in Table 3.

13 Extrapolated using data from the Bureau of Economic Analysis; 2016 is the latest available data. Please see methodology for more details.

14 Megawatts are units of power used to measure the output of a power station.

15 U.S. Energy Information Administration. State Profile and Energy Estimates, Massachusetts.

16 Massachusetts Clean Energy Center, Monthly Energy Numbers, January-November 2017.

17 Massachusetts Office of Energy and Environmental Affairs; Development of the Solar Massachusetts Renewable Target (SMART) Program, Mass.gov.

18 Governor Baker Signs Comprehensive Energy Diversity Legislation, Mass.gov.

19 2017 Energy Efficiency Scorecard, American Council for an Energy Efficient Economy.

20 U.S. Energy Information Administration. State Profile and Energy Estimates, Massachusetts.

21 MassSave Data, Public Time Series, 2010-2016. Extracted on September 22, 2017.

22 Massachusetts Department of Public Utilities Annual Report, 2016.

23 Massachusetts State Government, ESI Program Goals.

24 Massachusetts Clean Energy Center, ACES.

25 Massachusetts Department of Energy and Environmental Affairs, Renewable Heating and Cooling; Commonwealth Accelerated Renewable Thermal Strategy, Massachusetts Department of Energy Resources.

26 Massachusetts Clean Energy and Climate Plan for 2020, Massachusetts EEA, December 2015.

27 Massachusetts' Progress Towards Reducing Greenhouse Gas Emissions by 2020, Massachusetts EEA, 2015.

28 Massachusetts Executive Office of Energy and Environmental Affairs.

29 i3 Cleantech Group data.

30 National Science Foundation. Universities Report Four Years of Declining Federal Funding. November 2016.

31 National Science Foundation. Universities Report Four Years of Declining Federal Funding. November 2016.

32 Indirect and induced employment is based on an input-output model generated using Emsi's economic modeling tool.

33 Derwent Innovation, Clarivate Analytics, 2010-2016.

34 Derwent Innovation, Clarivate Analytics, 2010-2016.

35 Investment data is a compilation of the i3 Cleantech Group data, MassCEC grants database, Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) awards from the Department of Energy, Advanced Research Projects Agency for Energy (ARPA-E) awards, and SunShot grants. Please see Appendix A: Methodology and Data Sources for more detail. Stage one awards total roughly $255 million between 2010 and 2016 when using annual award amounts instead of three-year rolling averages.

36 Indirect and induced employment is based on an input-output model generated using Emsi's economic modeling tool.

37 Investment data is a compilation of the i3 Cleantech Group data, MassCEC grants database, Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) awards from the Department of Energy, Advanced Research Projects Agency for Energy (ARPA-E) awards, and SunShot grants. Please see Appendix A: Methodology and Data Sources for more detail. Stage two investments total roughly $328 million between 2010 and 2016 when using annual investment numbers instead of three-year rolling averages.

38 These represent annual investment totals, not the values presented in the three-year rolling averages.

39 The national analysis was conducted using only i3 investment data for Stage Three; investment types included part of Series A, Series B, Growth Equity, Structured Debt, Project Finance, Buyout/ Late-stage Private Equity, Follow-on Public Offering, Loan, Loan Guarantee, and PIPE investments.

40 Indirect and induced employment is based on an input-output model generated using Emsi's economic modeling tool.

41 Investment data is a compilation of the i3 Cleantech Group data, MassCEC grants database, Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) awards from the Department of Energy, Advanced Research Projects Agency for Energy (ARPA-E) awards, and SunShot grants. Please see Appendix A: Methodology and Data Sources for more detail. Stage three investments total roughly $4.1 billion between 2010 and 2016 when using annual investment numbers instead of three-year rolling averages.

42 Massachusetts Institute of Technology, Living Wage Calculator, 2017. The living wage for two working adults with two children is $16.83 per hour. Assuming a full-time job, or 1,850 hours per year, this comes out to roughly $31,000 per year for each individual or $62,000 combined.

43 Granular employment and establishment data that disaggregates by technology may not sum to high-level numbers due to rounding.

44 This does not indicate that only private equity is included. Rather, publicly traded companies and those operating exclusively on revenues from commercial projects are excluded from the dataset.

45 In previous years, these categories have been referred to as the "known" universe and "unknown" universe.

NOTES:

NOTES: